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Introduction

1.1 What is a HAPS?

A HAPS may seem a very simple concept, with an enormous potential. In the history of science and technology, there have been situations where very simple concepts have changed the world; the creation of the wheel is a clear example of this. Often, these inventions have come to life as a result of specific human needs which must be satisfied. Since the invention of radio waves in the nineteenth century, communication systems have become a priority, not only for military use, but also for civilian applications, with an increasing interest in having more demanding services from the users. This situation has motivated scientists and researchers to seek novel and innovative methods to provide broadband services throughout the wireless channel, serving a larger number of users and improving spectral efficiency.

The potential of HAPS is dawning on us slowly. The acronym HAPS is a term standing for 'high altitude platform stations', also known as stratospheric repeaters [WRC-122, 97], [ITU-F.592, 02]. HAPS is the name of a technology for providing wireless narrowband and broadband telecommunication and broadcasting services. HAPS aims to provide these services to users using either aircraft (manned or unmanned) or lighter-than-airships (LTA). These platforms are reusable and positioned at stratospheric altitudes, from 20 to 50 km approximately.

The International Telecommunications Union (ITU) published a report in 1998 which outlines HAPS as a new technology, entitled 'High Altitude Platform Stations: an opportunity to close the information gap' [ITU-Q/2, 98]. The ITU defines HAPS as a term referring to balloons or high-altitude aircraft that can be used to provide communication services [ITU-F.1399, 01], [ITU, 03]. A HAPS, in essence, is a radio relay in the sky.

The ITU has described HAPS as 'representing a new and long anticipated technology that can revolutionise the telecommunication industry'. It is the next generation of wireless communications infrastructure that can make efficient use of radio spectrum

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Alejandro Aragón-Zavala, José Luis Cuevas-Ruíz and José Antonio Delgado-Penín

resources, demonstrating greater system capacity, higher transmission quality and lower operating risk with the option to upgrade payload equipment at all times.

The idea of employing stratospheric platforms as flexible, non-pollutant and cost-effective alternatives to satellite or terrestrial systems is not new. Stratospheric platforms are widely recognised to be infrastructures able to yield integration and convergence of multiple general interest services.

Lighter-than-air vehicles that operate at very high altitudes have an obvious attraction for planners of surveillance, remote sensing and communication missions; i.e. the ability to see to a more distant horizon results in greatly expanded surveillance volumes, assuming that powerful sensors are carried onboard.

The idea of a stationary high-altitude relay platform (SHARP) was first conceived in 1980 in Canada. A 4.5 m wingspan scaled model of SHARP took its maiden flight on 17 September 1987 at the Communications Research Centre of Canada (CRC). This flight was repeated in 7 October 1987 and recognised as being the first of its kind by the *Fédération Aéronautique Internationale* [De Laurier, 85].

In recent years, increased emphasis has been placed on systems that can provide extended surveillance and communications support at such high altitudes. These are generically known as high-altitude long endurance (HALE) systems, high-altitude long loiter (HALL) systems or civilian applications of unmanned aircraft systems (CAUAS). HAPS are at a similar stage of development as communication satellites were in the 1960s.

HAPS are designed to fly above controlled airspace up to the stratosphere. From such a high altitude they are expected to carry out important aeronautical missions and applications. This altitude has been proposed to facilitate solar-powered station keeping, which requires a fairly benign environment. There is a *sweet spot* where wind and turbulence are minimal. It is an area of the atmosphere that is above the *Jet Stream 4* and below the upper layers of the stratosphere (between 20 and 30 km).

When hovering in geo-stationary flight, HAPS will also provide satellite-equivalent services, such as regional Earth system observations, i.e. communications with a terrestrial footprint diameter from 400 to 500 km. In order to provide such services, HAPS must be capable of long-endurance flight of weeks or months, which by itself introduces new concepts for multi-mission applications in terms of satellite navigation and unmanned aircraft traffic management; issues which are beyond the scope of this book.

Now, with efforts to expand commercial broadband services (particularly the so-called consumer's 'last mile') and the high cost of using satellites for that purpose, manufacturers are proposing HAPS, including fixed-wing aircraft and high-altitude airships (HAAs) to serve as surrogate satellites at a presumably reduced cost.

One of the main reasons why HAPS-based communication systems are highly favoured to provide these broadband services is its free-space-like path loss characteristic. For example, for a HAPS located at an altitude of 22 km, the path loss is comparable to that of a site located at the edge of a small terrestrial ground-based cell with a radius of 2.5 km.

Another important benefit of HAPS systems over satellites is the shorter delay that a signal travelling from a HAPS to a subscriber on the ground experiences, compared with that from a satellite link to ground. For example, for a low Earth orbit (LEO) satellite at 1390 km altitude, the one-way delay is about 5 ms, whereas for a HAPS located at 25 km of altitude, this delay is only 0.083 ms.

For terrestrial systems, and to overcome environmental constraints which affect the propagation of radio waves across all sorts of terrain characteristics, high antenna masts have been used, despite the lower path loss values obtained when compared with satellite communication systems. On the other hand, having considerable path losses at thousands of kilometres where communication satellites are deployed, satellite operators have pushed technology to develop sophisticated antennas and RF devices to guarantee the required quality-of-service which is demanded by the channel encountered under these conditions.

The HAPS is seen as a ‘middle ground’ between the terrestrial and satellite cases, and aims at exploiting potential benefits of intermediate altitudes between those used by the terrestrial and satellite technologies to provide broadband services to users, maximising capacity and spectral efficiency, with a reduction in cost and complexity.

1.2 Structure of the Book

The preceding section has given an insight into the world of HAPS, to help the reader understand the context upon which HAPS is established as a new technology. Following on from this introduction, the book is structured into four major sections.

The first section is concerned with introducing the concepts related to HAPS from a services and applications perspective, understanding the motivation behind the development of this technology. An overview to HAPS is given in Chapter 2, including state-of-the-art in the world and developments, operational frequencies allocated to HAPS systems as well as a comparison between HAPS and other terrestrial and satellite networks.

The next section (Chapters 3 and 4) provides a deeper analysis and description on the infrastructure required for HAPS to operate, with the causes and effects which may degrade link performance. Chapter 3 explains the propagation phenomena associated with the design of HAPS-based systems, emphasising the issues associated with these phenomena at the allocated frequency bands for HAPS. The need to characterise these effects follows, explaining the channel models used to date, for clear sky and rainy conditions. Chapter 4 contains an entire section on antennas for HAPS, a very important component of the HAPS system architecture and radio infrastructure. Issues related to antennas for the operating frequency bands allocated to HAPS have been carefully described, since they need to be taken into account when planning and designing an entire HAPS system.

The third section (Chapters 5 and 6) is devoted to communication systems based on HAPS. Chapter 5 starts with the elements of a HAPS-based communication system, followed by an overview on radio regulatory issues which affect the system, including several link budgets at HAPS operating frequencies for both rain and clear sky conditions. Once the system components which support HAPS networks have been explained, Chapter 6 introduces network topologies for HAPS, as well as covers radio resource management issues for a typical HAPS network.

Finally, the last section, covered in Chapter 7, aims to provide an authors' point of view on future HAPS developments and trends, unresolved research challenges and envisaged application and service opportunities.

References

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